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Lightweight Integrally Armored Floor (LIAF) Ballistic Testing

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14. ABSTRACT
As part of the Lightweight Integrally Armored Floor agreement between the Aviation Applied Technology Directorate and United Technologies Research Center, ballistic testing was conducted on six armored floor system test specimens. The purpose of this ballistic testing was twofold: to evaluate the performance of test specimen configurations against the 7.62x39 mm PS Ball projectile, and to provide data for improved ballistic modeling capability. The general configuration for each of the six tested armored floor test specimens consists of a strike face, a layer of ultra-high-molecular-weight polyethylene, and a mini-core sandwich structure which serves as the walking surface of the floor system. Four of the six specimens failed to stop the projectiles; however, two of the six were able to stop the projectiles. Those two specimens were subjected to additional shots at higher velocity after demonstrating initial stopping capability.

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PURPOSE

As part of the *Material Optimization and Testing* task of the *Lightweight Integrally Armored Floor* (LIAF) agreement between the Aviation Applied Technology Directorate (AATD) and United Technologies Research Center (UTRC), ballistic testing was conducted on six armored floor system test specimens. The purpose of this ballistic testing was twofold: to evaluate the performance of test specimen configurations against the 7.62x39 mm PS Ball projectile at 1,950 fps, and to provide data for improved ballistic modeling capability. The purpose of this test report is to document the results of the ballistic testing.

TEST EXECUTION

The subject ballistic testing was conducted on 16 March 2011 at the AATD Ballistic Test Range for Aircraft Component Survivability (BTRACS) facility, at Ft. Eustis, Virginia. The testing was conducted by Donald A. Campbell (range director), Mark E. Robeson (test engineer), Joseph A. Morro (range support), and Ronald E. Bowman (photography). The ballistic testing was witnessed by Connie Bird of UTRC.

TEST SPECIMENS

The general configuration for each of the six tested 12” x 12” armored floor test specimens consists of a strike face, a layer of ultra-high-molecular-weight polyethylene (UHMWPE), and a mini-core sandwich structure which serves as the walking surface of the floor system (Figure 1). Specimen details are covered in documents delivered under the AATD-UTRC LIAF agreement.

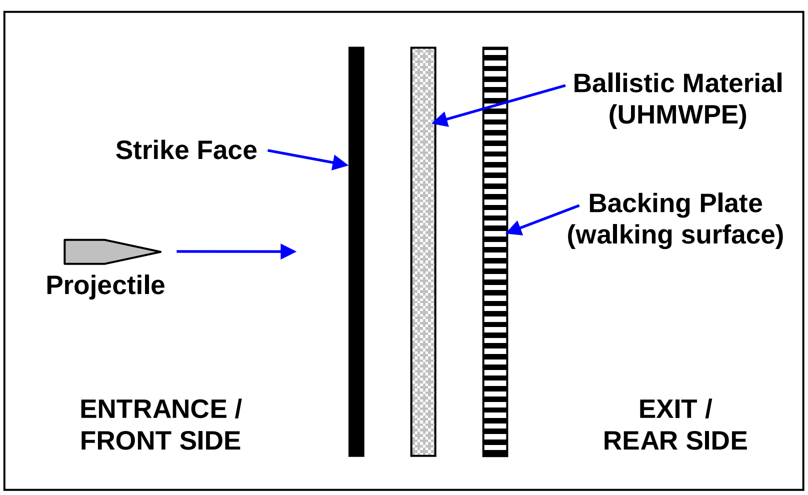

Figure 1. Armored floor test specimen configuration.

TEST SET-UP & PROCEDURES

All testing was performed indoors at room temperature ambient conditions. Each of the armored floor test specimens was mounted in a "picture frame" fashion with light clamping pressure in a test fixture (Figure 2). All shots were at 0° obliquity. An 0.020" aluminum witness plate was mounted six inches behind the test specimen during the testing. Instrumentation included a chronograph to measure and record projectile velocity, digital still cameras to record the test set-up and critical results, and high-speed video for the purpose of calculating exit velocity if a projectile were to penetrate a test specimen.

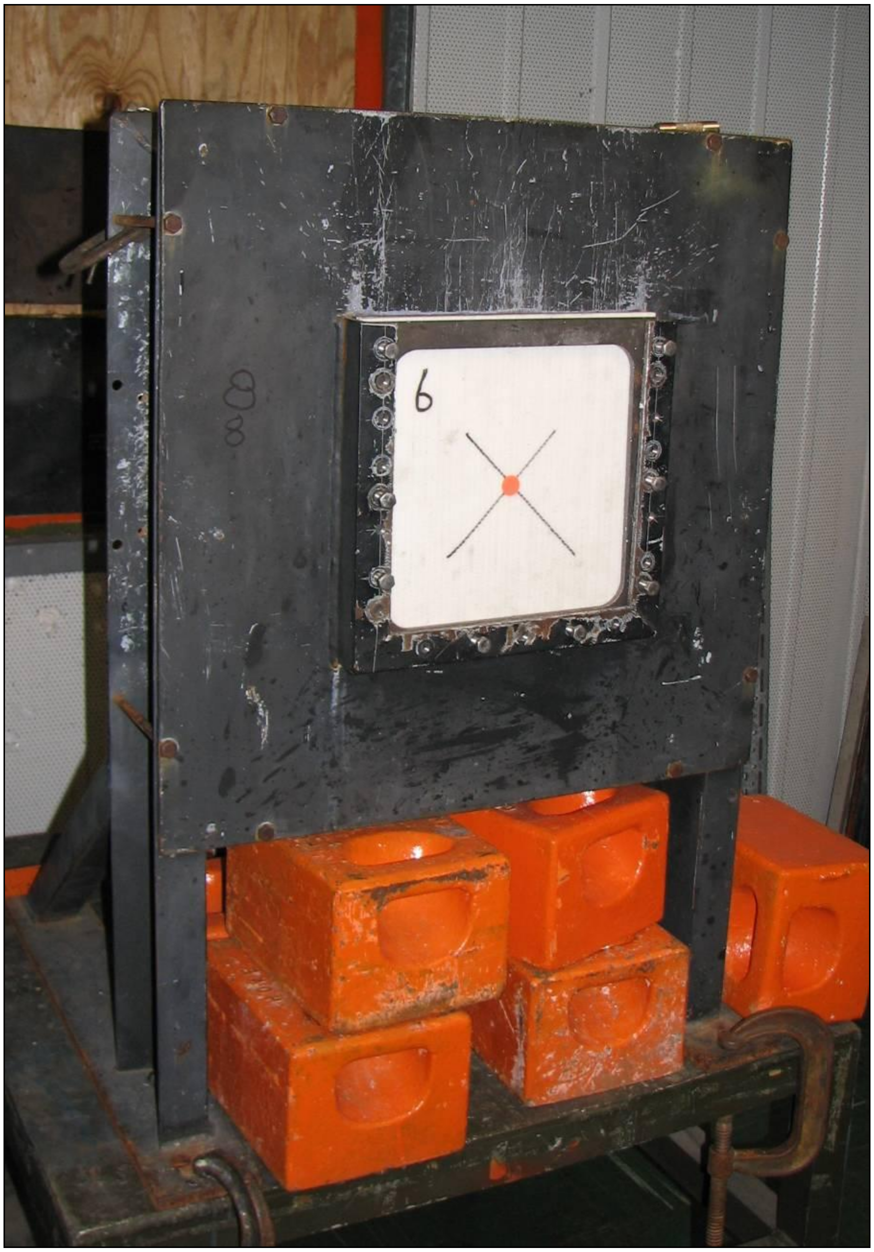

Figure 2. Test specimen in fixture.

In general, the test program was executed according to the following steps:

1. Mount test specimen in the fixture at 0° obliquity.
2. Position (bore sight) the gun.
3. Take pre-test still photographs of the test setup as necessary.
4. Load cartridge into the gun.
5. Start high speed video.
6. Fire the projectile and then safe the gun.
7. Stop high speed video.
8. Remove test specimen from the fixture.
9. Take post-test still photographs of the specimen.
10. Document impact velocity of the projectile, as well as performance and condition of the test specimen.
11. Calculate and record exit velocity of the projectile from high speed video, as appropriate.

TEST RESULTS

A total of nine shots were fired against the six test specimens using the 7.62x39 mm PS Ball projectile (Table 1). Discussion of the testing, by specimen, is in the sections that follow.

Table 1. Test matrix and summary of results.

Specimen #	Specimen Weight (lb)	Shot #	Impact Vel (fps)	Exit Vel (fps)	Notes / Observations
1	4.66	1	1883	1346	specimen penetrated
2	4.77	2	1923	899	specimen penetrated
3	4.83	3	1928	1340	specimen penetrated
4	5.07	4	1947	N/A	projectile stopped
		4A	2154	N/A	projectile stopped
5	4.86	5	1965	N/A	projectile stopped
		5A	2201	1340	specimen penetrated
		5B	2123	1265	specimen penetrated
6	5.41	6	1988	1533	specimen penetrated

Specimen 1

Specimen 1 was shot one time with the 7.62x39 mm PS Ball projectile at 1,883 fps. The projectile completely penetrated the specimen (Figure 3); exit velocity was calculated from high-speed video to be 1,346 fps. Damage on the strike face was very localized. However, the backing plate (the walking surface of the floor system) showed delamination extending outward from the shot location. Overall, the specimen remained integral and rigid.

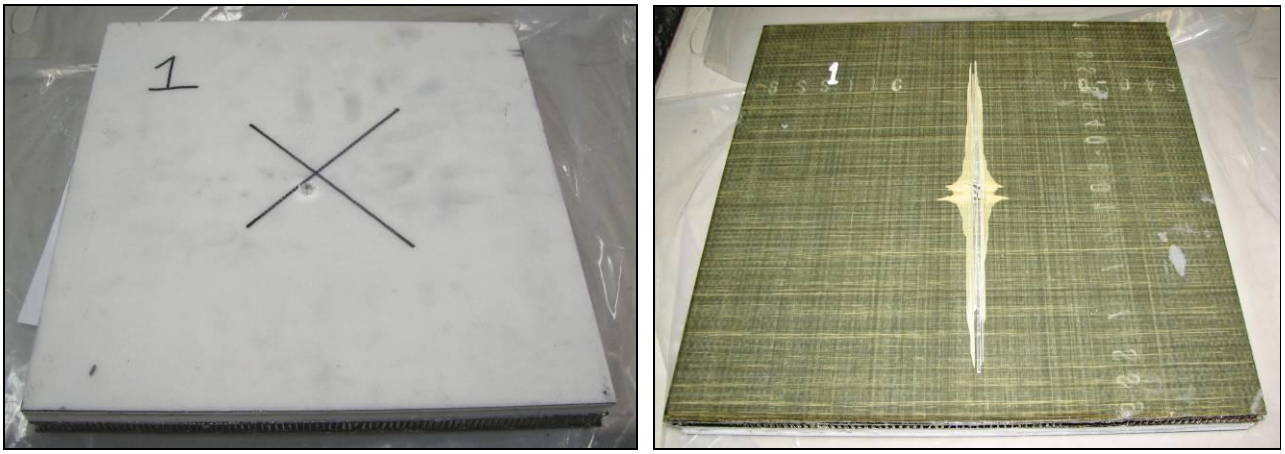

Figure 3. Strike face (right) and backing plate (left) of Specimen 1, post-test.

Specimen 2

Specimen 2 was shot one time with the 7.62x39 mm PS Ball projectile at 1,923 fps. The projectile completely penetrated the specimen (Figure 4); exit velocity was calculated from high-speed video to be 899 fps. Damage on the strike face was very localized. However, the backing plate (the walking surface of the floor system) showed delamination extending outward from the shot location. Overall, the specimen remained integral and rigid.

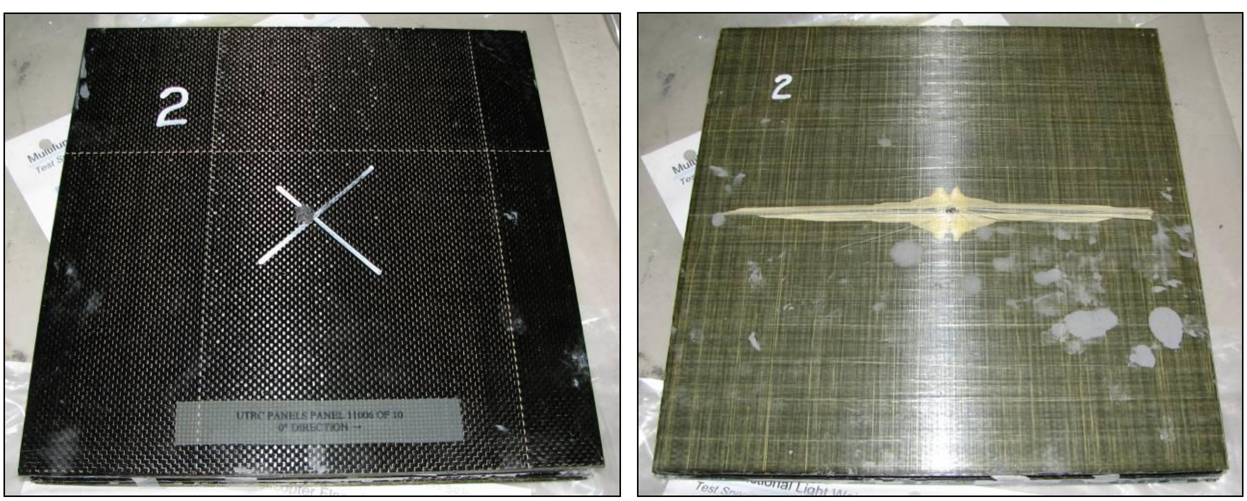

Figure 4. Strike face (right) and backing plate (left) of Specimen 2, post-test.

Specimen 3

Specimen 3 was shot one time with the 7.62x39 mm PS Ball projectile at 1,928 fps. The projectile completely penetrated the specimen (Figure 5); exit velocity was calculated from high-speed video to be 1,340 fps. Damage on the strike face was very localized. However, the backing plate (the walking surface of the floor system) showed delamination extending outward from the shot location. Overall, the specimen remained integral and rigid.

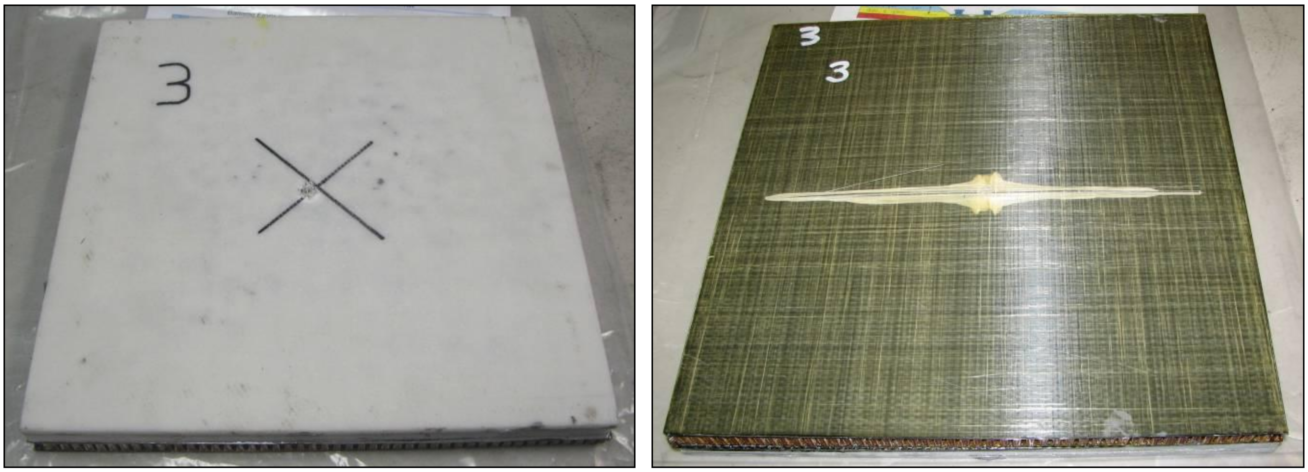

Figure 5. Strike face (right) and backing plate (left) of Specimen 3, post-test.

Specimen 4

Specimen 4 was shot two times with the 7.62x39 mm PS Ball projectile, at 1,947 fps and 2,154 fps, respectively. Both projectiles were stopped by the specimen (Figure 6). Damage on the strike face was very localized. However, the backing plate (the walking surface of the floor system) showed delamination extending outward from the location of one of the shots; the location of the other shot had very localized delamination. No interaction between the damage areas was evident. Overall, the specimen remained integral and rigid.

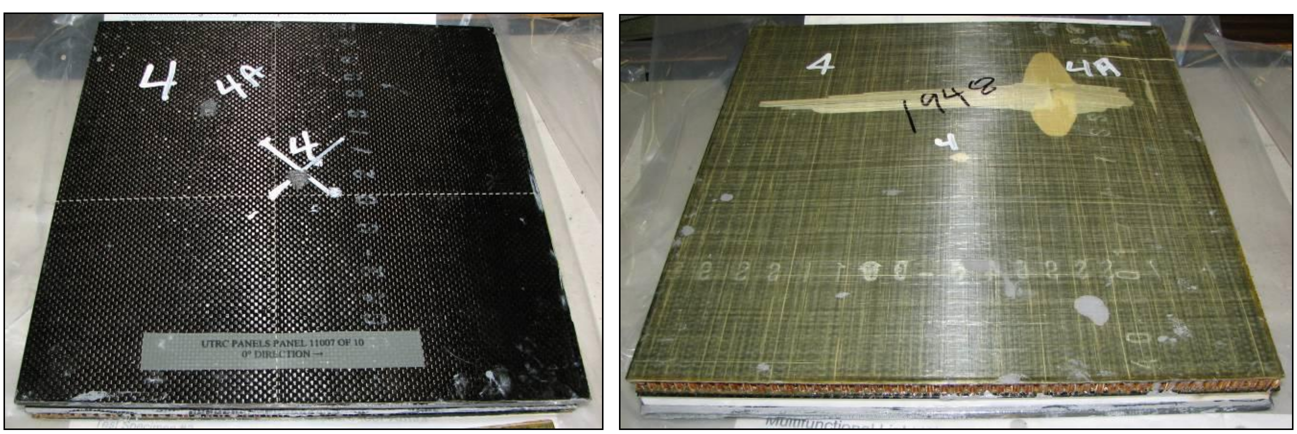

Figure 6. Strike face (right) and backing plate (left) of Specimen 4, post-test.

Specimen 5

Specimen 5 was shot three times with the 7.62x39 mm PS Ball projectile (Figure 7). The first shot, at 1,965 fps, was stopped by the specimen. The second shot, at 2,201 fps, completely penetrated the specimen; exit velocity was calculated from high-speed video to be 1,340 fps. The third shot, at 2,123 fps, also completely penetrated the specimen; exit velocity was calculated from high-speed video to be 1,265 fps. Damage on the strike face was very localized. However, the backing plate (the walking surface of the floor system) showed delamination extending outward from the locations of the penetrating shots. There was no indication of delamination on the backing plate at the location of the shot that was stopped. No interaction between the damage areas was evident. Overall, the specimen remained integral and rigid.

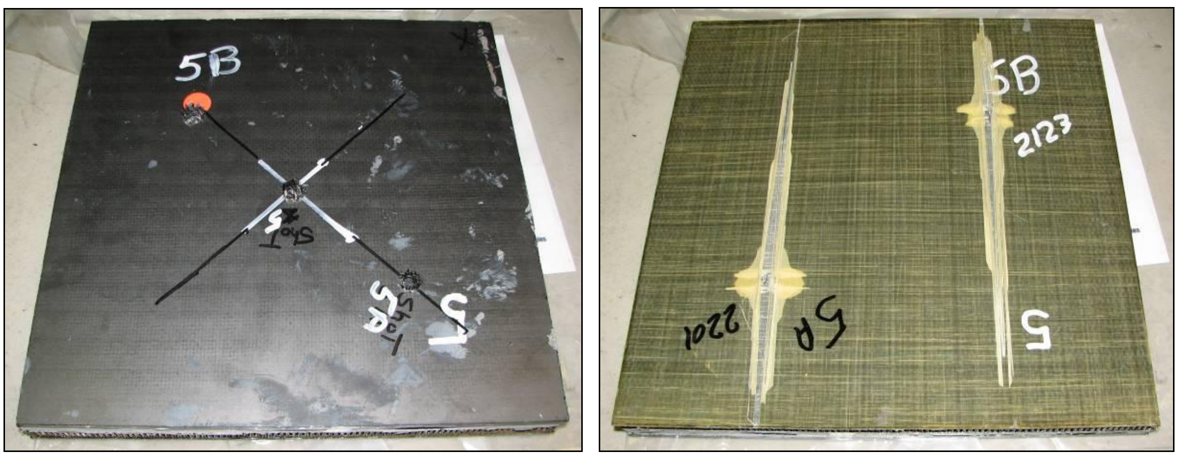

Figure 7. Strike face (right) and backing plate (left) of Specimen 5, post-test.

Specimen 6

Specimen 6 was shot one time with the 7.62x39 mm PS Ball projectile at 1,988 fps. The projectile completely penetrated the specimen (Figure 8); exit velocity was calculated from high-speed video to be 1,533 fps. Strike face damage was very localized. However, the backing plate (the walking surface of the floor) showed delamination extending outward from the shot location. Overall, the specimen remained integral and rigid.

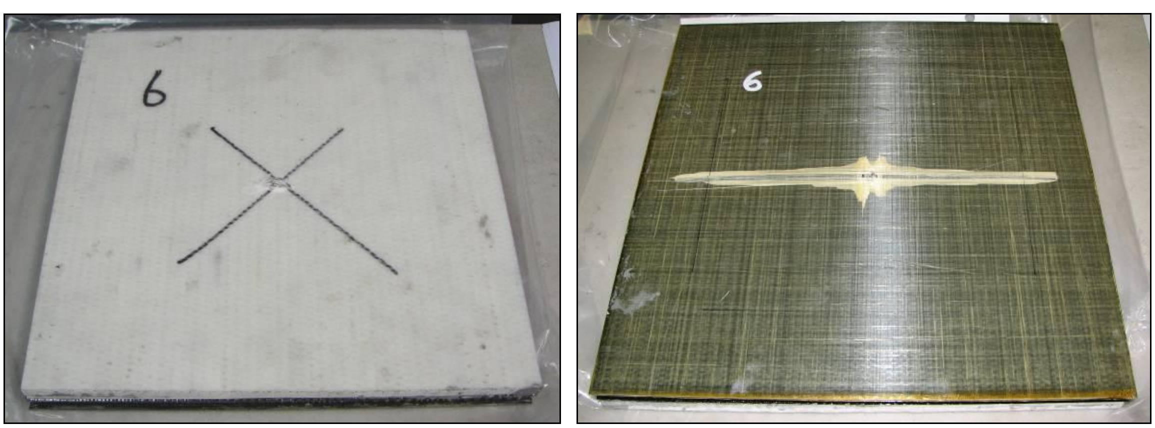

Figure 8. Strike face (right) and backing plate (left) of Specimen 6, post-test.

Projectile Core Hardness

The 7.62x39 mm PS Ball projectile contains a mild steel core. Among the ballistic testing community, there is concern that the core hardness varies considerably from ammunition lot to lot, and that this variation affects armor test results significantly. While a comprehensive core hardness study is beyond the scope of this testing, measuring core hardness for the present testing was a reasonable contribution to any future core hardness study. To that end, a projectile was pulled from the ammunition lot used for the present testing, and the steel core of this projectile was hardness tested.

The hardness of the projectile core was tested using a 0.25” shape correction factor and a 1/16” ball indenter, and measured on the Rockwell HRB scale. For a sample size of 13 indentations, the mean value was 89.33, with a standard deviation of 7.98. The maximum reading was 95, and the minimum was 69, with a process capability index C_p of 1.04.

CONCLUSIONS

The test matrix (Table 1) was successfully completed. Velocities, photographic data, and high-speed video were recorded. Four of the six specimens failed to stop single projectiles; however, two of the six were able to stop single projectiles. Those two specimens were subjected to additional shots at velocities higher than the objective of 1,950 fps after demonstrating initial stopping capability. Specimen 4 stopped an additional round. Specimen 5 was unable to stop either of two additional rounds.

MISCELLANEOUS

The photographs produced during this ballistic testing have been provided to UTRC under separate cover. The test specimens were returned to UTRC soon after the testing.

ACKNLOWLEDGMENTS

Funding for the *Lightweight Integrally Armored Floor* (LIAF) agreement (W911W6-06-2-0001) between AATD and UTRC is provided by the Joint Aircraft Survivability Program Office (JASPO), with cost share from UTRC. LIAF is JASPO project number V-10-01.

POINT OF CONTACT

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